

Distillation optimization

* It is the technique followed to pay the minimum amount of money yearly.

* ex

For a distillation column \Rightarrow the yearly cost includes:

- a) steam cost b) cooling water cost
c) pumping cost (if the feed requires pumping)
 \downarrow
 low w.r.t a, b

d) Maintenance \Rightarrow (15-20% of the fixed capital investment)
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\therefore The steam and cooling water has a large load on the yearly cost

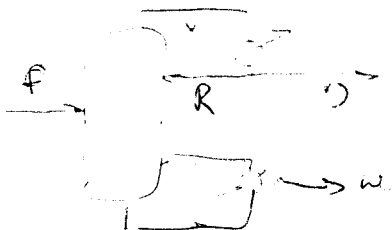
* Annual cost $\begin{cases} \text{fixed} \Rightarrow (\text{depreciation, maintenance}) \\ \text{operating} \end{cases}$

* But, there's a very important factor in the distillation column which is the reflux ratio. But the reflux ratio must be optimized

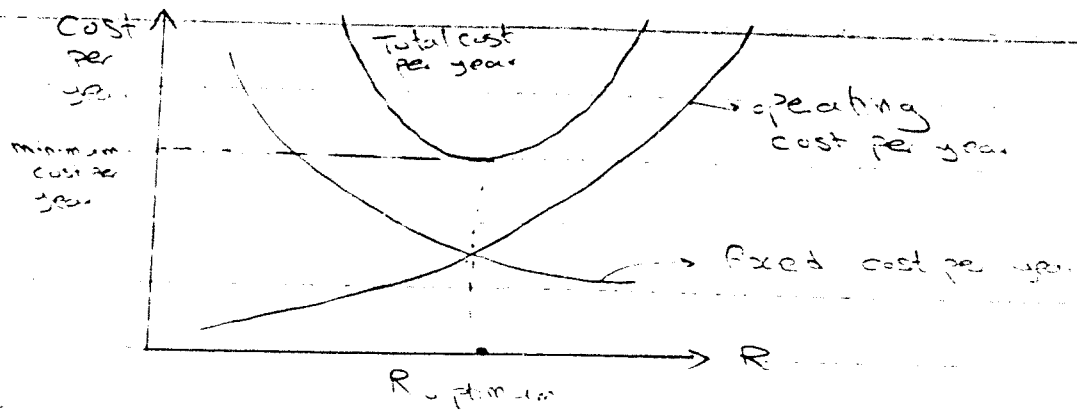
i) As $R \uparrow$, driving force \uparrow , no. of actual plates $\downarrow \Rightarrow$ F.C.I. \downarrow

ii) As $R \uparrow$, vapor load \uparrow , $Q_c \uparrow$, $m_{cw} \uparrow$, $a_r \uparrow$, $m_{steam} \uparrow \Rightarrow$ operating cost \uparrow
 $v = (v_{\text{ref}}) \cdot R$

\therefore As $R \uparrow$, fixed cost per year \downarrow & operating cost per year \uparrow



* Saying that $R_{op} = 1.25 R_{min}$ isn't accurate
(This is because energy cost is variable). So
there's always controller on the reflux ratio



and we can readjust the feed fraction

where

$$\text{Total cost per year} = \text{operating} + \text{fixed cost per year}$$

Another ex

To choose a pipe diameter for the domestic water flow which needs to be pumped.

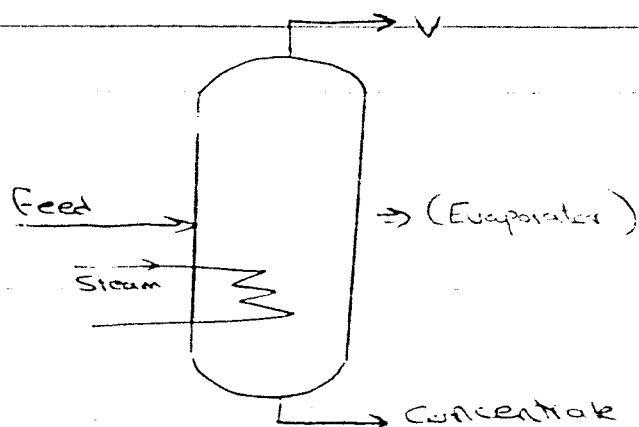
- Fixed cost!
- i) If pipe diameter \uparrow , Fixed cost $\uparrow \Rightarrow$ maintenance cost \uparrow
 - ii) If pipe diameter \downarrow , friction \uparrow , cost of pumping $\uparrow \Rightarrow$ operating cost!

so we need optimum pipe diameter

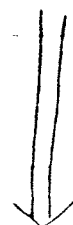
Peters (page 388)

we will photocopy this example from the doctor





* Calculate the optimum number of effects needed



* As no. of effects ↑, Fixed cost ↑, operating cost ↓

as amount of steam will be low.

Ex

60,000 lb H_2O from salt solution will be evaporated, where the cost of 1st effect = 18,000 and cost of any other effect is 15,000. Service life = 10 and salvage value = 0. If the fixed charges are 15% of the FCI, and maintenance is 5% of FCI. $m_{water} = 0.95 N$. Steam cost is \$0.5 per 1000 lb steam. get optimum no. of stages to reach the same separation

Solution

$$FCI = 18,000 + 15,000 (N-1)$$

$$Dep. Cost/year = \frac{18,000 + 15,000 (N-1) - 0}{10} = \checkmark$$

$$\therefore \text{fixed cost/year} = (0.15 + 0.05) [18,000 + 15,000 (N-1)] + (\checkmark) = \text{€}$$

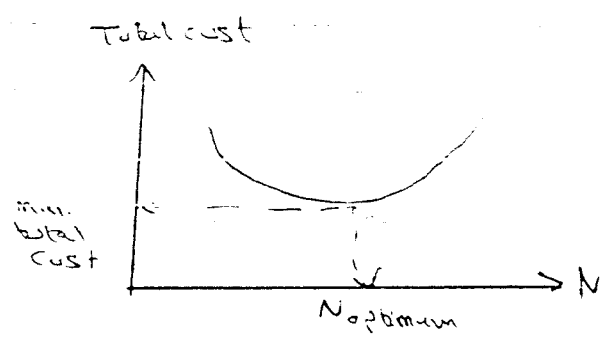
$$m_{\text{Steam}} = \frac{60,000 \frac{\text{lb water}}{\text{day}} \times 300 \frac{\text{day}}{\text{year}}}{0.95 N \frac{\text{lb water}}{\text{lb steam}}} = \text{€} \frac{\text{lb steam}}{\text{year}}$$

$$\therefore \text{Steam cost/year} = \frac{\text{---}}{\text{---}} \times \frac{0.5}{1000}$$

(This is the operating cost)

* Then add fixed and operating cost to get total cost as a function in N . Then ~~draw~~ sub. by more than one value of $N \Rightarrow$ and get the corresponding total cost

N	total cost
✓	✓
✓	✓
✓	✓



(If $N_{\text{optimum}} = 3.8 \Rightarrow$ sub. in the total cost equation ~~by~~ (3) once ~~and~~ by (4) once \Rightarrow then, choose the N corresponding to minimum total cost.

* optimum outlet temp. of cooling water in condense

$$Q = m_{cw} c_{pw} (T_{ocw} - T_{icw}) = m_{hf} c_{phf} (T_{ihf} - T_{ohf}) = U_0 A H.T \Delta T_m$$

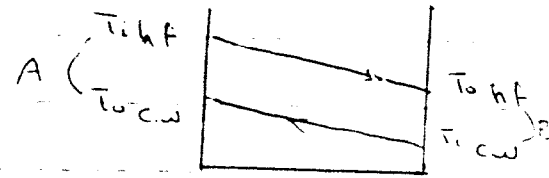
($m_{hf}, c_{phf}, T_{ihf}, T_{ohf}$ are constants \Rightarrow so Q is constant)

\therefore As $T_{ocw} \uparrow, m_{cw} \downarrow \Rightarrow$ operating cost \downarrow

(U_0 can be considered constant. Actually it's function

in type of heat exchanger and type of cold and hot fluid).

* AS $T_{ocw} \uparrow$, $\Delta t_m \downarrow \Rightarrow \infty$ Area of heat transfer \uparrow
 \Downarrow
 ∞ F.C.I $\uparrow \Rightarrow$ Fixed cost \uparrow



$$\Delta t_m = \frac{A - B}{\ln A/B}$$